§6. Establishment of Small Specimen Test Technique for Fracture Toughness Evaluation of Reduced Activation Ferritic Steels towards Highly Efficient Utilization of High Energy Neutron Source

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Small specimen test technology for evaluation of fracture toughness has been developed to apply to blanket structural materials. The advantages utilizing small specimen are 1) reduction of irradiation volume for material surveillance test using neutron source, 2) development of new methodology to evaluate rather thin structural materials as a spin-off technology. Miniaturization of specimen for fracture toughness measurement, however, often results in the disadvantage that the obtained fracture toughness does not meet the validity criterion. The objective of this research is to develop small specimen test technology to evaluate fracture toughness of fusion blanket structural materials.

Miniaturized compact tension specimens were produced from a thick plate of JLF-1 steel that has been considered to be the prime candidate for blanket structural materials. Figure 1 shows a brief geometry of the specimens. The 1CT is the standard specimen and the 1/2CT and 1/4CT is the specimen whose specimen volume is reduced to 1/8 and 1/16 of the standard specimen, respectively. The fatigue pre-crack was induced and side grooves were fabricated to increase constraint on the crack front. The numerical data of fatigue pre-cracks induced in the miniaturized compact tension specimens are summarized in Table 1. Fracture toughness measurement is now underway.

The finite element method was applied to investigate stress state near notch root of Charpy V-notch specimens. The used calculation code was WARP3D, which permit the use of elastic-plastic elements and three-dimensional analysis. Elastic and plastic deformation parameters were determined from the stress-strain curves experimentally obtained at each temperature. As for finite element, so-called 8 nodes-hexahedra was used, and the number of elements was around 1200. Stress components in a plane ahead of notch root for each size of specimen were calculated The FEA showed that ductile-brittle transition appears to be correlated with plane stress state condition at specimen surface; the ratio of plane stress state to plane strain state region becomes larger at higher temperature, in smaller specimen and in more ductile material. Further simulation study is necessary to explain the size effect on ductile to brittle behavior.

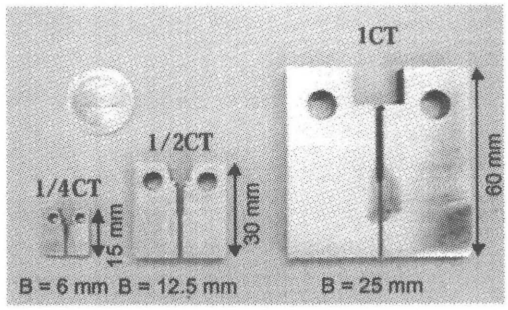

Fig.1. Miniaturized compact tension specimens to evaluate fracture toughness of fusion structural materials (JLF-1 steel).

試験片サイズ	試験片符号	最大荷重 (N)	最小荷重 (N)	周波数 (Hz)	き裂長さ		繰返し数 N(回)
					a1 (mm)	a2 (mm)	
1CT	A	4903	245	30	2.60	2.50	136000
1/2CT	B1	2942	147	30	0.20	0.20	100000
		3236	167	30	2.10	1.90	215000
	B2	3236	167	30	2.10	2.00	182000
	B3	3432	177	30	2.20	2.00	159000
	B4	3432	177	30	2.10	2.00	154000
	B5	3432	177	30	2.10	2.00	155000
	B6	3432	177	30	2.00	2.00	156000
1/4CT	C1	981	49	30	1.50	1.50	170000
	C2	981	49	30	1.50	1.50	174000
	C3	981	49	30	1.40	1.40	181000
	C4	981	49	30	1.50	1.50	167000
	C5	981	49	30	1.50	1.40	167500
	C6	981	49	30	1.50	1.50	172000

Table 1. Numerical data of fatigue pre-cracks induced in the miniaturized compact tension specimens for fracture toughness measurement.

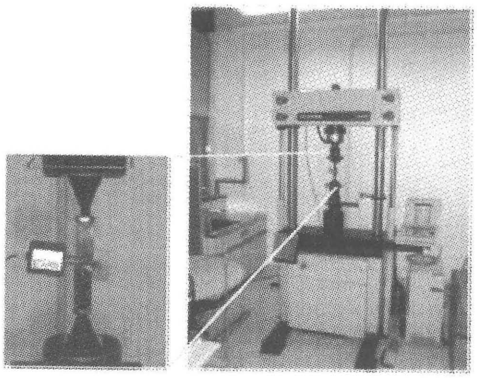

Fig.3. Fracture toughness testing machine with a loading capacity of 25tons.